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TITLE: 248-nm LASER DAMAGE TESTING OF LIF

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ABSTRACT

We have tested several samples of LIF, both single crystal and press forged, for damage resistance to 10-ns 248-nm pulses at 35 pps. The damage thresholds - the highest levels at which no damage could be produced - ranged from 4-6 J/cm^2 although some test sites survived irradiation at ~30 J/cm^2. We observe that bulk damage is the primary failure mechanism in single crystal and press forged samples and that both types exhibit the same resistance to laser damage.

248-nm LASER DAMAGE TESTING OF LIF

Ultraviolet window materials such as lithium fluoride are susceptible to three types of laser-induced damage: surface damage, bulk damage, and color-center formation. In recent tests of seven samples - both single crystal and press forged - we have observed bulk damage as the primary failure mechanism.

Test conditions are listed in Table I.

TABLE I.

wavelength	248 nm
mean $1/e^2$ spot diameter	0.6 nm
pulsewidth (FWHM)	11 ns
pulse rep. frequency	35 pps

In all tests - except one series that is described later - the incident beam was focused on the front surface of the sample. Since the majority of damage sites were located in the bulk material at a depth of up to 2 mm, it is of interest to plot the laser fluence as a function of depth in the crystal. Figure 1 is such a plot, which is obtained by extrapolating measurements made in air, and ignoring the possibility of self-focusing.

Bulk damage as observed in these tests was distinctly nonsubtle. A bright spark was followed immediately by the creation of a large (~0.25 - 1.0 mm) fracture site that was star-like in appearance. Frequently a bulk spark was observed, which persisted for tens of shots before extinction, leaving no permanent visible record. These sites were listed in the "no damage" category.

On a few samples, some surface sparks were observed with ~5% of all damage sites having increased surface scattering features after testing. However, due to the poor quality of these uncleaned surfaces and the observation that well polished surfaces exhibited no damage, we conclude that the surface damage threshold exceeds that of the bulk material in these tests.

All samples fluoresced under irradiation. While careful transmission measurements have not yet been made, our qualitative observation was that there was neither reduced transmission, nor increased fluorescence in tests at 11 J/cm^2 for 10^5 shots. No visible color centers were formed at this level.

The data for a Harshaw single crystal sample are plotted in Fig. 2 along with a linear regression fit (dotted line). The 0% intercept defines the damage threshold and the upper limit is the 100% level - 4 J/cm^2 and 12 J/cm^2 respectively. Data for the strongest sample and the weakest are represented by solid lines; all results for the remaining samples fell within these boundaries. Table II is a compilation of observations for each sample.

It should be noted that all sites damaged within the first few shots or not at all for 1000 shots - the duration of a typical test.

It is interesting to compare single-crystal and press-forged samples. While press forging improves many mechanical properties of LIF, it is apparent from Table III that similar improvement in damage resistance is not obtained. However, as is evident from the last column in Table II, the press-forged <u>data</u> exhibits a significantly greater degree of scatter (lower regression coefficients) than is seen in the single crystals.

TABLE II

SUMMARY OF RESULTS

Supplier	Identification	Type	Size (mm × mm)	Damage Threshold (J/cm^2)	Upper Limit (J/cm^2)	Fluorescence	Regression Coefficient
Meller	#10	single crystal	26 × 4.1	2.5	10	bright yellow white	0.91
Honeywell	H-61	press forged	38[1] × 10.7	3.8	15	faint blue	0.85
Harshaw	#16	single crystal	26 × 8.0	4.0	12	faint blue	0.97
Harshaw	#17	single crystal	26 × 8.0	4.4	27[2]	faint blue	0.99
Honeywell	H-39, section 1	press forged	~45 × 6.2	4.5	19	very faint	0.65
Honeywell	H-39, section 2	press forged	~45 × 6.3	5.5	15	very faint	0.77
Honeywell	H-64	single crystal	32 × 9.9	6.0	33[2]	faint blue	0.82

1- square sample
2- extrapolated upper limit

TABLE III

AVERAGED PROPERTIES OF SINGLE CRYSTAL
VS. PRESS-FORGED LITHIUM FLUORIDE

	Single Crystal	Pressed Forged
damage threshold (J/cm^2)	4.2 ± 1.5	4.6 ± 0.9
upper limit (J/cm^2)	21 ± 11	16 ± 2
regression coefficient	0.92 ± 0.07	0.76 ± 0.10

In order to verify the validity of the damage thresholds, each part was subjected to a second test. Since the standard test involves irradiating 10 discrete sites at a given fluence and plotting the number of sites which damaged, one possible objection is that testing 10 sites is not statistically significant: a weak spot might be missed. As a check, the beam was scanned continuously across the surface in a systematic search for vulnerable sites. The scan covered about 10 mm^2, while the coverage of a standard test is about 4 mm^2. In all seven samples, scanning verified the standard test results: sub-threshold scans produced no damage.

Again, bulk damage was observed as the primary failure mechanism in all samples tested. However, as a consequence of electric field superposition, it is well known that the back surface is more susceptible to damage than the front. In these tests, the highly divergent beam was focused at the front surface and the back was subjected to a much lower fluence. As a result, the question of bulk damage resistance relative to the back surface had not been addressed.

An abbreviated test with the focus at the back surface was conducted to answer this question. Twenty-five sites were irradiated at a level above the upper limit on one sample. All sites damaged with five of the failures being on the back surface. Again however, the poorly polished and uncleaned surface (red fluorescence at the rear damage sites are suggestive of surface contamination) cast doubt on the significance of the observed surface damage, and lead us back to the original conclusion that bulk damage is the primary failure mechanism in LiF.

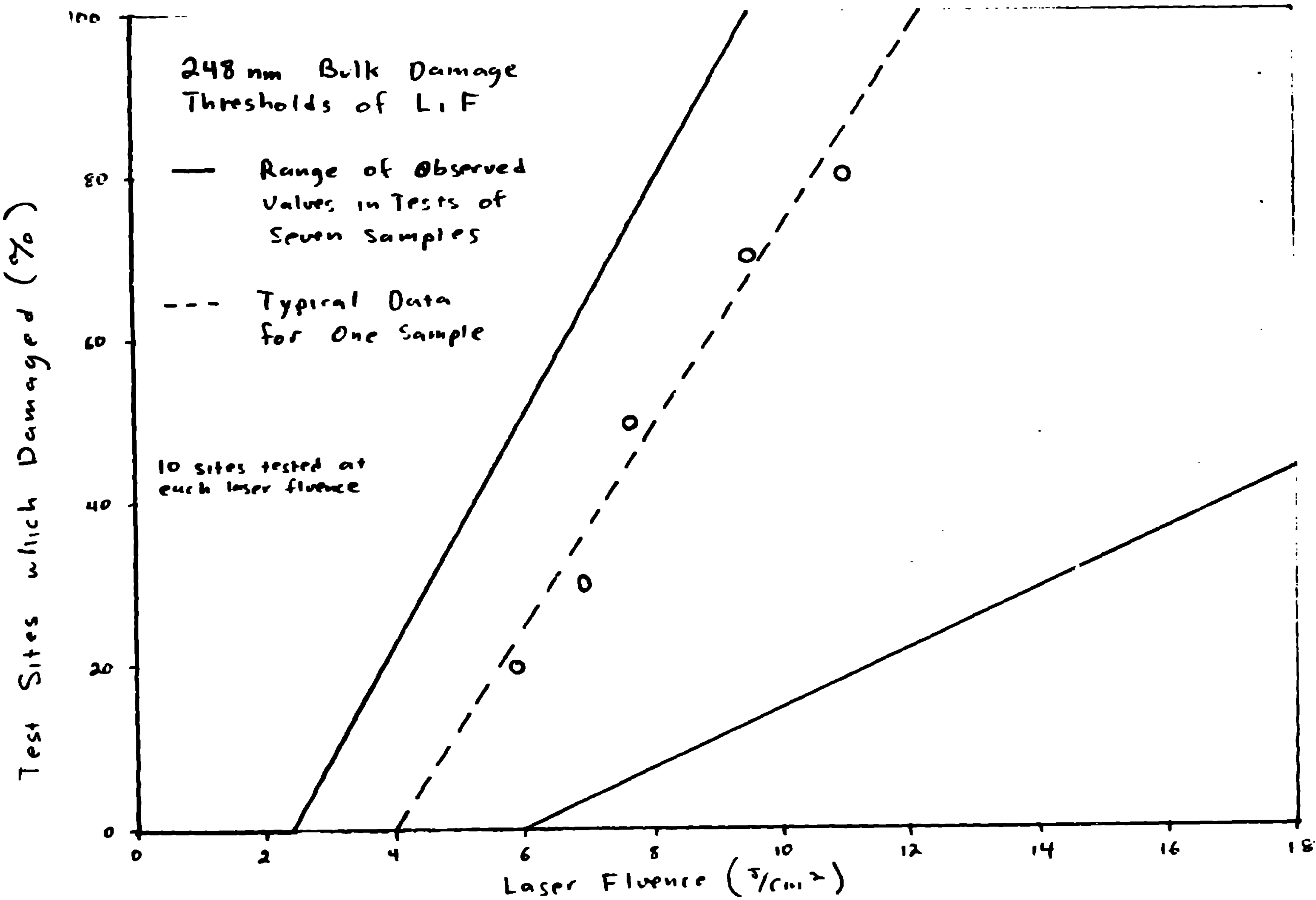
248 nm Bulk Damage Thresholds of LiF
Range of Observed Values in Tests of Seven Samples
Typical Data for One Sample
10 sites tested at each laser fluence
Test Sites which Damaged (%)
Laser Fluence (J/cm²)
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18

Fig 2

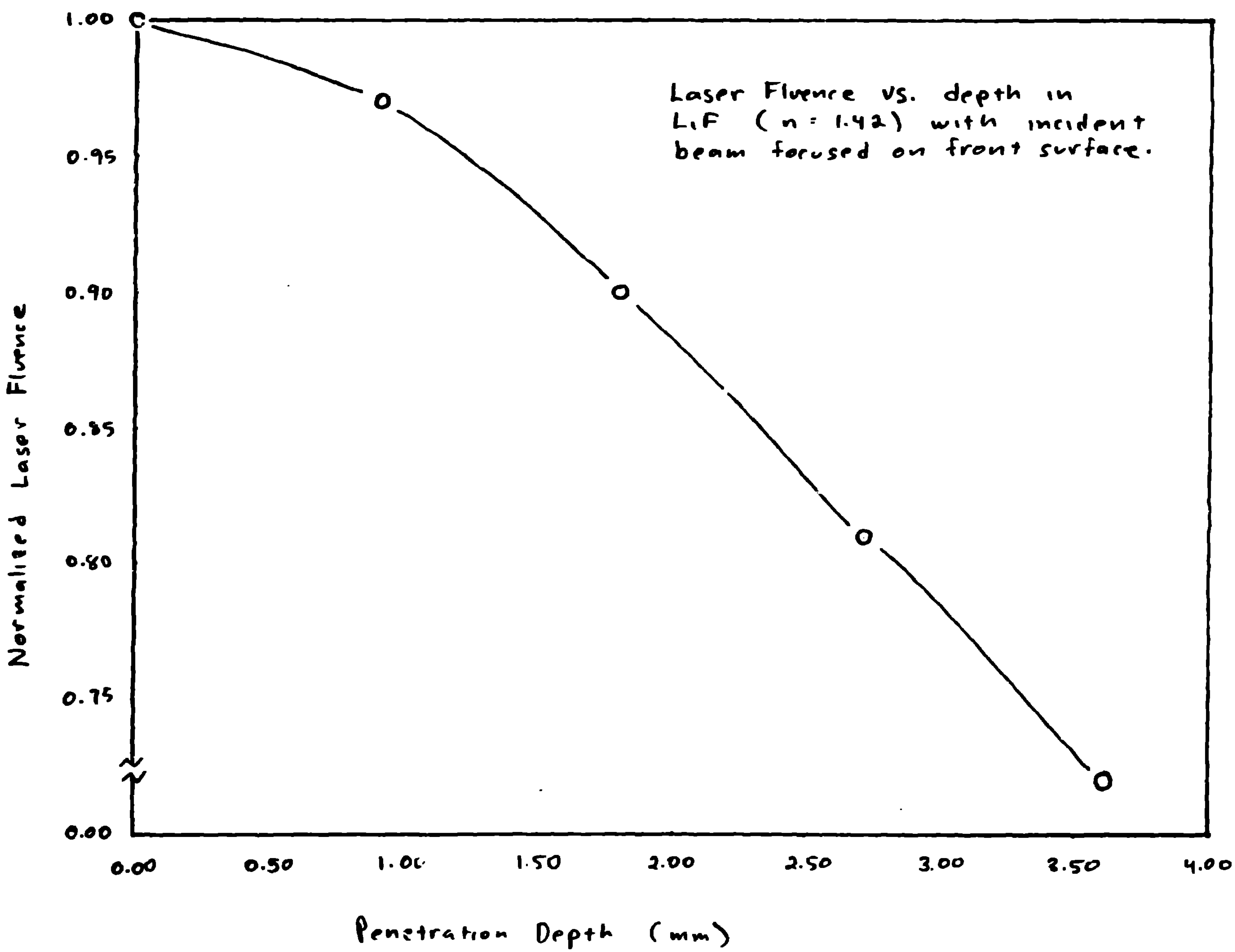
Laser Fluence vs. depth in LiF (n = 1.42) with incident beam focused on front surface.
1.00
0.95
0.90
0.85
0.80
0.75
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Normalized Laser Fluence
Penetration Depth (mm)

Figure 1.